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OFFSHORE ECOLOGICALLY AND BIOLOGICALLY SIGNIFICANT AREAS IN THE SCOTIAN SHELF BIOREGION

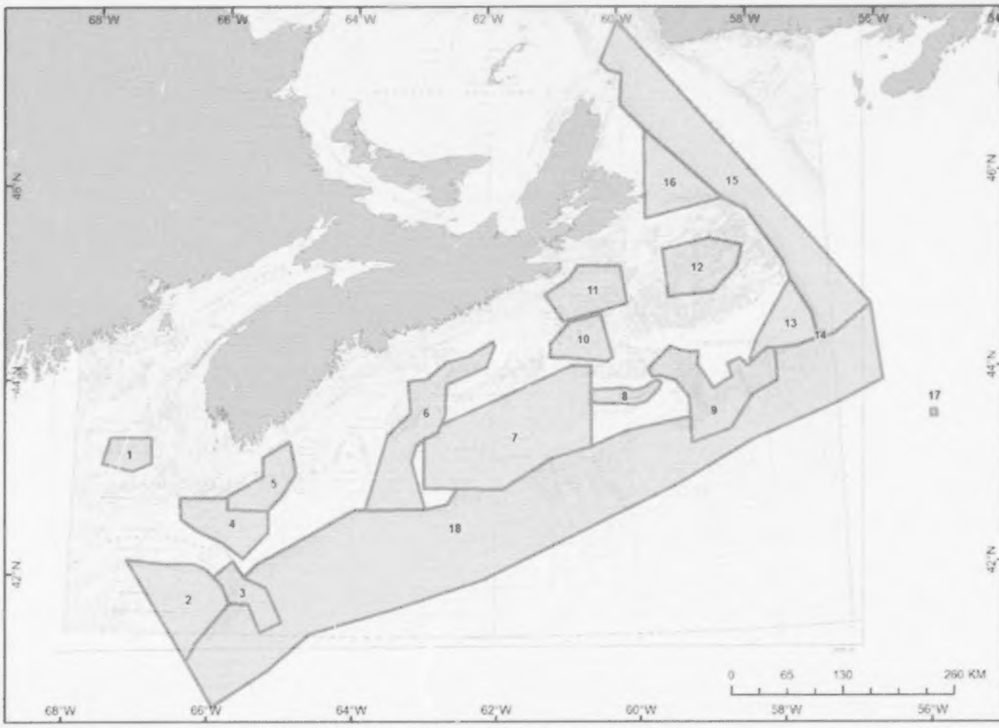

Figure 1. Ecologically and Biologically Significant Areas for the offshore component of the Scotian Shelf Bioregion: (1) Jordan Basin and the Rock Garden, (2) Canadian portion of Georges Bank, (3) Northeast Channel, (4) Browns Bank, (5) Roseway Basin, (6) Emerald Basin and the Scotian Gulf, (7) Emerald-Western-Sable Island Bank Complex, (8) Sable Island Shoals, (9) Eastern Scotian Shelf Canyons, (10) Middle Bank, (11) Canso Bank and Canso Basin, (12) Misaine Bank, (13) Eastern Shoal, (14) Stone Fence, (15) Laurentian Channel, (16) St. Anns Bank, (17) Laurentian Fan Cold Seep Communities, (18) Scotian Slope.

Context

Canada's Oceans Act (1997) authorises Fisheries and Oceans Canada (DFO) to conserve and protect living aquatic resources and their supporting ecosystems through the creation of Marine Protected Areas (MPA) and MPA networks, and to provide enhanced management to areas of the oceans and coasts via the development of Integrated Oceans Management Plans. Ecologically and Biologically Significant Areas (EBSAs) are areas that warrant a greater-than-usual degree of risk aversion in the management of activities due to their particularly high ecological or biological significance (DFO 2004). Identifying EBSAs is not a general strategy for protecting all species, habitats or communities that have some ecological significance (DFO 2004), but EBSAs will inform broader oceans planning and management processes and be considered in the design of bioregional MPA networks (Government of Canada 2011).

This Science Advisory Report (SAR) is from the February 18-20 and March 24, 2014 Updating Offshore Ecologically and Biologically Significant Areas in the Scotian Shelf Bioregion. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

SUMMARY

- Eighteen Ecologically and Biologically Significant Areas (EBSAs) were described and delineated in the offshore component of the Scotian Shelf Bioregion. Seventeen of the EBSAs occur on the Scotian Shelf or Scotian Slope and one EBSA was identified in the deeper waters beyond the slope.
- The approach used to refine the list of EBSAs consisted of an evaluation of the Scientific Expert Opinion EBSAs based on available broad-scale ecological and biological data and a review of the literature. Notable ecological and biological features under the different DFO EBSA criteria were highlighted for each EBSA.
- One-hundred and forty-nine ecological or biological data layers were compiled or created to help evaluate and identify EBSAs in the offshore component of the Scotian Shelf Bioregion. The data layers were organized under the themes of: areas of high biological productivity or biomass, areas of high fish and invertebrate diversity, important habitats for fishes and invertebrates, coral and sponge occurrences, Critical Habitat for species at risk, important areas for seabird functional guilds, and distinct physical conditions.
- Specifically, the following data layers were presented:
  - Areas of persistent, relatively high chlorophyll concentrations (as an index of phytoplankton biomass) in the Scotian Shelf Bioregion using satellite-derived MODIS ocean colour data from the National Aeronautics and Space Administration.
  - Areas of high fish and invertebrate biomass on the Scotian Shelf using the DFO summer Research Vessel (RV) data.
  - Three species diversity indices, Species Richness, Heip's Evenness Index and the exponential of Shannon-Weiner Index, for fishes and invertebrates using the DFO RV data.
  - Important habitat layers for a suite of fish species using summer, spring and fall DFO RV survey data.
  - Coral and sponge occurrences using data from the Maritimes Region Coral Database.
  - Critical Habitat for the Endangered North Atlantic Right Whale and Northern Bottlenose Whale.
  - Areas of high relative abundance for eight seabird functional guilds using data from Environment Canada.
  - Distinct physical conditions based on previous research to identify areas with different scope for growth and natural disturbance regimes.
- A more systematic, data-driven approach could have been applied; however, such a method would have produced results that were skewed toward highly sampled components of the bioregional ecosystem (i.e., demersal fishes). The approach that was employed made use of available broad-scale data while also considering smaller scale, site-specific research findings and expert knowledge.
- Where appropriate, EBSA boundaries were aligned with recognized physical, ecological or biological features, such as the underlying bathymetry.
- Significant gaps exist in the available ecological and biological data for the Scotian Shelf Bioregion. For instance, less information is available for the slope and deeper-water environments than the shelf; demersal environments are generally better-studied than the pelagic and mesopelagic realms; and synoptic distribution information is not available for certain taxonomic groups (e.g., cetaceans, sharks, tunas, sponges).

- Further investigation is required to refine several of the larger EBSAs, such as the Scotian Slope, Laurentian Channel, and Georges Bank. Other available survey data should be analyzed to identify the most ecologically and biologically significant locations within these broadly defined EBSAs. Discrete physical features (e.g., submarine canyons) should also be delineated and described within these EBSAs.
- The DFO RV data were used to create many of the data layers considered in this analysis so it is important to acknowledge the limitations of these surveys. For example, certain parts of the shelf are not sampled due to untrawlable bottom types. The seasonal coverage of the RV data is also limited, and the RV survey gear does not capture all species equally.
- The initial analysis to identify areas of persistent, relatively high chlorophyll concentrations in the Bioregion should be refined by splitting the shelf waters into eastern and western components due to the differences in the oceanographic environments of these areas. Separate seasonal layers should also be developed to account for the significant variability in chlorophyll concentrations throughout the year.
- Additional analysis is required to further characterize the spatial and temporal patterns in biodiversity in the Bioregion. To fully contribute meaningful scientific advice about the biodiversity on the Scotian Shelf, functional trait diversity, such as diversity of trophic guilds, size structure and other metrics must be explored in addition to extending the suite of species included in the diversity analysis presented here. Where sufficient relative distribution information does not exist, habitat modelling approaches can be explored to predict where the most important habitats are for certain species.
- The EBSAs and the individual EBSA data layers presented in this report will be considered in a broad range of coastal and oceans management and planning processes in the Scotian Shelf Bioregion, including environmental assessments, environmental emergency response, sustainable fisheries policies and Marine Protected Area network planning. Each EBSA will undergo an evaluation to identify potential management needs.

BACKGROUND

Over the past decade, DFO has made considerable progress on identifying Ecologically and Biologically Significant Areas (EBSAs) in Canadian waters. In the Scotian Shelf Bioregion, which roughly corresponds to the DFO Maritimes Region boundary, there have been several projects to identify EBSAs using a variety of approaches (e.g., Buzeta and Singh 2008, Doherty and Horsman 2007, Gromack et al. 2010, Kenchington et al. 2010, Maclean et al. 2009, Horsman et al. 2011). In March 2012, DFO Maritimes held a Regional Science Advisory Process (RAP) to develop initial advice on the objectives, ecological data and methods that should be considered in designing a network of Marine Protected Areas (MPAs) in the bioregion (DFO 2012). One of the recommendations was to re-evaluate the offshore Scientific Expert Opinion (SEO) EBSAs described by Doherty and Horsman (2007). Updating EBSAs is a specific deliverable for Maritimes Region under the Health of the Oceans (HOTO) initiative. The primary objective of the current Science Advisory Process is to review and provide advice on a refined list of EBSAs for the offshore component of the Scotian Shelf Bioregion.

EBSAs are areas of particularly high ecological or biological significance compared to other areas in a region (DFO 2004). A greater than usual degree of risk aversion may be required in the management of activities affecting EBSAs. The identification of an area as an EBSA does not give it any special legal status or automatically trigger a management response. The EBSAs and the individual EBSA data layers presented in this report will be considered in a broad range of coastal and oceans management and planning processes in the Scotian Shelf Bioregion, including environmental assessments, environmental emergency response, sustainable

fisheries policies and MPA network planning. Each EBSA will undergo an evaluation to identify potential management needs. The evaluations will consider the nature and extent of human activities and the level of risk posed by those activities to important ecological features.

DFO (2004) and the Convention on Biological Diversity (CBD 2009) have developed separate criteria for the identification of EBSAs, but it is generally expected that using either set of criteria will result in the identification of the same or similar areas (DFO 2012). The DFO (2004) criteria are summarized as:

- *Uniqueness*: Areas that contain unique, rare, or distinct features in a regional, national or global context.
- *Aggregation*: Areas where significant numbers of a species or a wide variety of species are found during some period of the year, or areas where a structural feature or ecological process is observed in exceptionally high density.
- *Fitness Consequences*: Areas where important life-history activities (e.g., reproduction) that strongly affect the fitness of a species or population take place.
- *Resilience*: Areas that include habitat structures or species that are highly sensitive, easily perturbed, and/or slow to recover.
- *Naturalness*: Relatively pristine areas with little to no evidence of human influence.

The CBD (2009) EBSA criteria are summarized as:

- *Uniqueness or rarity:* Areas that contain a unique, rare, or endemic species, population, community, habitat or ecosystem or an unusual geomorphological or oceanographic feature.
- *Special importance for life-history stages of species:* Areas required for a population to survive and thrive (e.g., breeding or nursery grounds, spawning areas, migratory species habitat).
- *Importance for threatened, endangered or declining species and/or habitats*: Areas that contain habitat that is critical for the survival and recovery of endangered, threatened, or declining species or significant assemblages of endangered, threatened, or declining species.
- *Vulnerability, fragility, sensitivity, or slow recovery*: Areas that contain a high proportion of sensitive habitats, biotopes, or species that are especially susceptible to degradation or depletion, and/or are slow to recover.
- *Biological productivity*: Areas that contain species, populations, or communities with comparatively higher natural biological productivity.
- Biological diversity: Areas with comparatively higher diversity of ecosystems, habitats, communities, or species, or that display high genetic diversity.
- *Naturalness:* Areas that exhibit a comparatively higher degree of naturalness resulting from little to no anthropogenic pressure.

The DFO criteria have been used as the primary basis for evaluating and identifying EBSAs in the Scotian Shelf Bioregion. However, the CBD EBSA criteria have also been considered because the EBSAs may be used by other federal or provincial departments, will be considered in the shared federal (Parks Canada and Canadian Wildlife Service)/provincial (Nova Scotia and New Brunswick) MPA network planning process, and may eventually be submitted to the international EBSA repository under development by the CBD. Table 1 illustrates how the DFO and CBD EBSA criteria could align (Buzeta 2014).

Table 1. Suggested alignment of the CBD (2009) and DFO (2004) EBSA criteria (based on Buzeta 2014). Shading indicates overlap. Dash indicates no overlap.

CBD (2009)	DFO (2004)				
	Uniqueness	Aggregation	Fitness Consequences	Resilience	Naturalness
Uniqueness or rarity	overlap	-	-	-	-
Special importance for life-history stages of species	-	overlap	overlap	-	-
Importance for threatened, endangered or declining species and/or habitats	-	overlap	overlap	-	-
Vulnerability, fragility, sensitivity, or slow recovery	-	-	-	overlap	-
Biological productivity	-	overlap	-	-	-
Biological diversity	-	overlap	-	-	-
Naturalness	-	-	-	-	overlap

ASSESSMENT

Approach Used to Refine EBSAs

The approach used to refine the list of EBSAs consisted of an evaluation of the previously described SEO EBSAs (Doherty and Horsman 2007) based on available broad-scale ecological and biological data and a review of the literature. The SEO EBSAs were identified through an expert workshop and encompass many of the same areas identified through other approaches (e.g., Breeze 2004, Maclean et al. 2009).

A qualitative approach that was informed by available broad-scale ecological and biological data was used to evaluate each SEO EBSA. Data layers that are relevant to the various EBSA criteria were compiled or created based on guidance provided through the previous advisory process (DFO 2012). Published data layers were assembled, certain existing data layers were updated using more recent data, and new data layers were created using available broad-scale survey data. An overlay analysis was then completed to determine the extent to which the SEO EBSAs captured the different data layers. This step provided supporting evidence for the original rationale provided by Doherty and Horsman (2007) and highlighted any additional ecological and biological features that occur in each EBSA. All layers were weighted equally in the overlay analysis. A literature review was also carried out to identify further supporting evidence or additional features for each area. Notable ecological and biological features under the different DFO EBSA criteria were highlighted for each EBSA. At this stage, several SEO

EBSAs for which minimal supporting evidence was found were removed from the process. It must be acknowledged that the approach used to evaluate and update EBSAs has certain limitations. Most notably, using the SEO EBSAs as a starting point for the process constrained the exercise from the outset. A more systematic, data-driven approach could have been applied; however, such a method would have produced results that were skewed toward highly sampled components of the bioregional ecosystem (i.e., demersal fishes). The approach that was employed made use of available broad-scale data while also considering smaller scale site-specific research findings and expert knowledge. However, it did not explicitly consider areas there were not previously identified through the SEO exercise.

Where appropriate, EBSA boundaries were aligned with recognized physical, ecological or biological features, such as the underlying bathymetry. In some cases, overlapping EBSAs or areas that were immediately adjacent to one another were combined into one larger EBSA. The current EBSA boundaries should still be considered approximate.

The data layers used in the evaluation and the proposed set of EBSAs were presented for review. Some data layers and certain EBSA boundaries were further refined based on the feedback received.

EBSA Data Layers and Criteria Application

One-hundred and forty-nine ecological or biological data layers were compiled or created to help evaluate and identify EBSAs in the offshore component of the Scotian Shelf Bioregion. Table 2 provides a summary of the data layers that were used in the overlay analysis and indicates the DFO and CBD criteria associated with each. The data layers were organized under the themes of: areas of high biological productivity or biomass, areas of high fish and invertebrate diversity, important habitats for fishes and invertebrates, coral and sponge occurrences, Critical Habitat for species at risk, important areas for seabird functional guilds and distinct physical conditions. The focus was placed on compiling available broad-scale survey data that can be used to characterize the relative distribution of specific ecological or biological features (e.g., populations, species, habitats) or characteristics (e.g., species richness).

Table 2. Summary of data layers compiled or created for the offshore component of the Scotian Shelf Bioregion and the DFO and Convention on Biological Diversity EBSA criteria that have been associated with each layer. Numbers in parentheses indicate the number of layers in each category. DFO EBSA criteria abbreviations: U = Uniqueness, A = Aggregation, FC = Fitness Consequences, R = Resilience, and N = Naturalness. CBD EBSA criteria abbreviations: U = Uniqueness, LH = Life History Stages, ET = Endangered or Threatened Species, VS = Vulnerable Species, P = High Biological Productivity, D = High Biodiversity, and N = Naturalness. Dash indicates that criteria are not considered to be applicable.

EBSA Data Layers and Source Data	DFO Criteria					CBD Criteria						
	U	A	FC	R	N	U	LH	ET	VS	P	D	N
Areas of high biological productivity or biomass												
Areas of high chlorophyll concentrations (100-1500m) (MODIS[1] ocean colour data) (1)	-	x	x	-	-	-	-	-	-	x	-	-
Areas of high chlorophyll concentrations (>1500m) (MODIS ocean colour data) (1)	-	x	x	-	-	-	-	-	-	x	-	-
Fish biomass (1970-2012)(RV[2] data) (1)	-	x	-	-	-	-	-	-	-	x	-	-
Fish biomass (1978-85)(RV data) (1)	-	x	-	-	-	-	-	-	-	x	-	-
Invertebrate biomass (1999-2012)(RV data) (1)	-	x	-	-	-	-	-	-	-	x	-	-
Areas of high fish and invertebrate diversity												
Fish species richness (RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Invertebrate species richness (RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Fish species evenness (RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Invertebrate species evenness (RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Fish species diversity (ESW[3])(RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Invertebrate species diversity (ESW)(RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Small fish species richness (stomach contents from RV data) (1)	x	x	x	-	-	x	x	-	-	-	x	-
Small invertebrate species richness (stomach contents from RV data) (1)	x	x	-	-	-	x	-	-	-	-	x	-
Larval fish genus richness (SSIP[4] data) (1)	x	x	x	-	-	x	x	-	-	-	x	-
Important habitat for fishes and invertebrates												
Important summer habitat for fish species (1970-2012)(RV data) (34)	-	x	-	x	-	-	-	x	x	x	-	-
Important spring habitat for fish species (1979-85)(RV data) (30)	-	x	-	x	-	-	-	x	x	x	-	-
Important fall habitat for fish species (1978-84)(RV data) (30)	-	x	-	x	-	-	-	x	x	x	-	-
Important summer habitat for invertebrates (1999-2013)(RV data) (16)	-	x	-	-	-	-	-	-	-	x	-	-
Larval fish abundance (8)	-	x	x	-	-	-	x	x	-	-	-	-
Critical Habitat for Endangered Species												
Endangered whale Critical Habitat (2)	-	x	x	-	-	-	x	x	-	-	-	-
Leatherback turtle Critical Habitat (1)	-	x	x	-	-	-	x	x	-	-	-	-
Corals and sponges												
Coldwater coral occurrences (ROV[5], FOP[6], RV data) (1)	x	x	-	x	x	x	-	-	x	-	x	x
Sponge occurrences (ROV, FOP, RV data) (1)	x	x	-	x	x	x	-	-	x	-	x	x
Areas of high sponge density (RV data) (1)	x	x	-	x	x	x	-	-	x	-	x	x
Important areas for seabirds												
Important areas for seabird functional guilds (Environment Canada data) (8)	-	x	x	-	-	-	x	x	-	-	-	-
Distinct physical conditions												
Areas of very high scope for growth	-	-	x	-	-	-	-	-	-	x	-	-
Areas of very low scope for growth	-	-	-	x	-	-	-	-	x	-	-	-
Areas of very low natural disturbance	-	-	-	x	-	-	-	-	x	-	-	-

[1]Moderate Resolution Imaging Spectroradiometer; [2]Research Vessel; [3]Exponential of Shannon-Weiner Index; [4]Scotian Shelf Ichthyoplankton Program; [5]Remote Operated Vehicle; [6]Fisheries Observer Program

The majority of the EBSA data layers in Table 2 address the Aggregation criterion, which results in a bias towards this criterion. Examples include areas of persistent high chlorophyll concentration, areas of high fish and invertebrate biomass, important habitats for fishes and invertebrates, and important areas for seabird foraging guilds. Most of the evidence of the Uniqueness of a particular EBSA was derived from the literature and based on smaller scale, site-specific research, such as the location of corals and sponges. Evidence for the Fitness Consequences criterion was also obtained mostly from the literature, although certain EBSA data layers did point to possible nursery and spawning areas (e.g., larval fish abundance). Further analysis of the DFO Research Vessel (RV) data and food habits data could help identify areas where important life-history stages occur for certain species. The Resilience and Naturalness criteria are generally used to help prioritize among EBSAs (DFO 2004). Evidence of both was noted where possible, but little information was available on the Naturalness of the EBSAs.

Areas of High Biological Productivity or Biomass

Areas of persistent, relatively high chlorophyll concentrations (as an index of phytoplankton biomass) in the Scotian Shelf Bioregion were mapped using satellite-derived MODIS ocean colour data from the National Aeronautics and Space Administration. The data for the period of 2002-2012 were divided into 48 quarter-month segments from January to December. A 10-year climatology map was generated for each segment. The data were also split into shelf waters (100-1500 m) and deep water (>1500 m) to account for the fact that average chlorophyll concentrations are much higher on the shelf than over the deeper parts of the Bioregion. A threshold of one half of a standard deviation above the mean was set to define areas of high chlorophyll concentrations for each quarter-month climatology in each sub-region. A mask was created for each climatology by assigning a value of one to all pixels above the threshold and a value of zero to all remaining pixels. The individual masks were then combined (added) to produce a final map for each sub-region that shows the frequency (percentage) that each pixel had a value above the threshold over the 48 time segments (Figure 2).

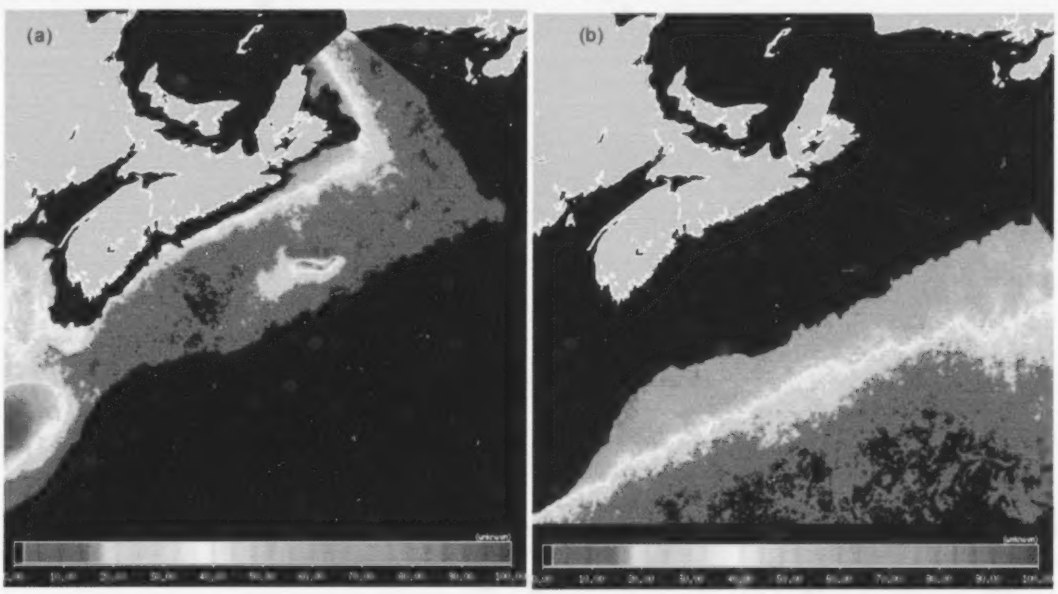

Figure 2. Areas of persistent, relatively high chlorophyll concentrations in the offshore component of the Scotian Shelf Bioregion. A relative index was generated for two sub-regions: (a) shelf waters (100-1500 m) and (b) the deeper portions of the bioregion (>1500 m). Average chlorophyll concentrations are significantly higher on the shelf than in deeper waters.

Areas of high fish and invertebrate biomass on the Scotian Shelf were mapped using the DFO summer RV data. The total biomass caught per tow was calculated and a continuous surface was created using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles and the areas within the top quintile (i.e., top 20%) were considered areas of high biomass. For fish, this analysis was done for the two time periods of 1970-2012 and 1978-1985. The period of 1978-1984 was a time of groundfish recovery when the biomass of most commercial stocks was relatively high (Horsman and Shackell 2009) (Figure 3). Data from 1999 to 2012 were used for the invertebrate layer because invertebrates have only been regularly recorded in the RV survey since 1999 (Tremblay et al. 2007). It was recommended that data from 2007 to present could be used to create habitat layers for a broader suite of species because species identification has been more reliable since that time.

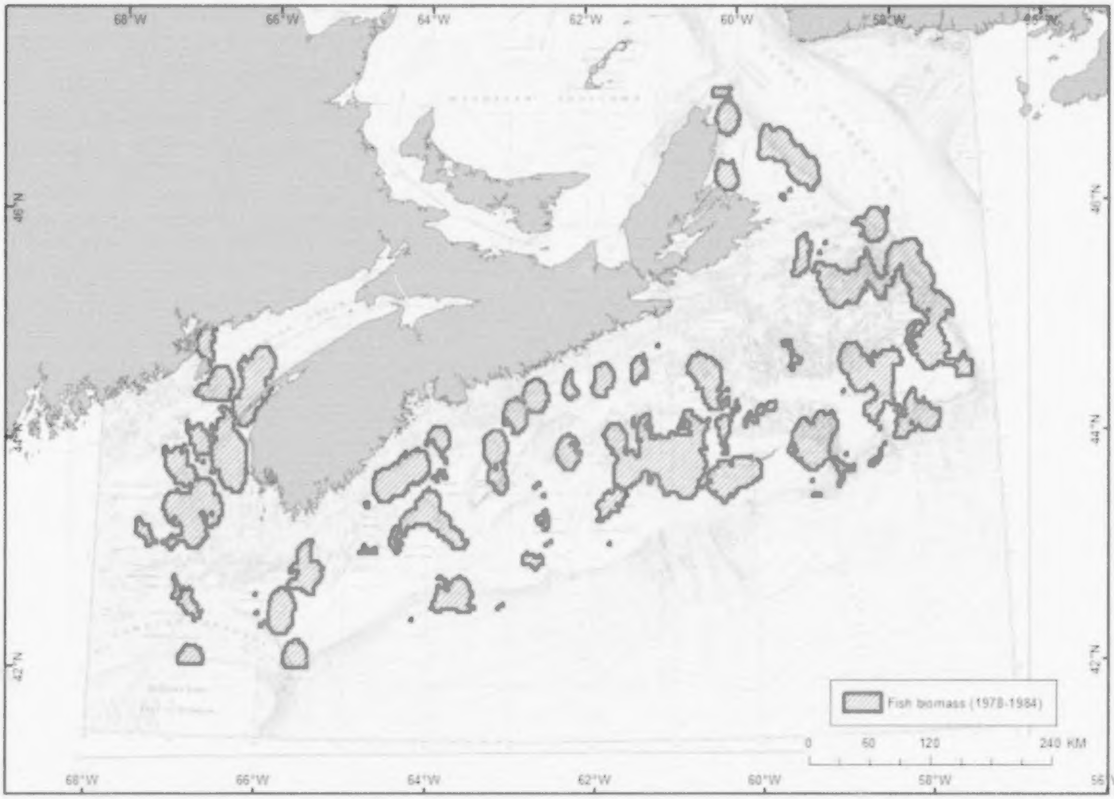

Figure 3. Areas of high fish biomass for the period of 1978 to 1984 based on the DFO summer Research Vessel data.

Areas of High Fish and Invertebrate Diversity

The preliminary results of a fish and invertebrate diversity analysis were presented for discussion. Three species diversity indices were mapped for fishes and invertebrates using the DFO summer RV data. As suggested by Kenchington and Kenchington (2013), the indices considered were Species Richness, Heip's Evenness Index, and the exponential of Shannon-Weiner Index (ESW). For fish, the indices were plotted for four fishing eras between 1970 and 2013, and a composite layer was created for each index by combining the layers for the four time periods. For invertebrates, the initial analysis used data from 1999 to 2013, but it was recommended that years prior to 2007 be excluded because the identification of invertebrates has been more reliable and consistent since that time. Thus, the period of 2007 to 2013 was used. The data layers were then classified into quintiles and the areas within the top quintile

(top 20%) were considered areas of high diversity. Figure 4 provides an example of one of the invertebrate diversity layers (Heip's Evenness Index). Small fish and invertebrate Species Richness layers developed by Cook and Bundy (2012) and the larval fish Genus Richness layer created by Shackell and Frank (2000) were also considered in the EBSA evaluation exercise.

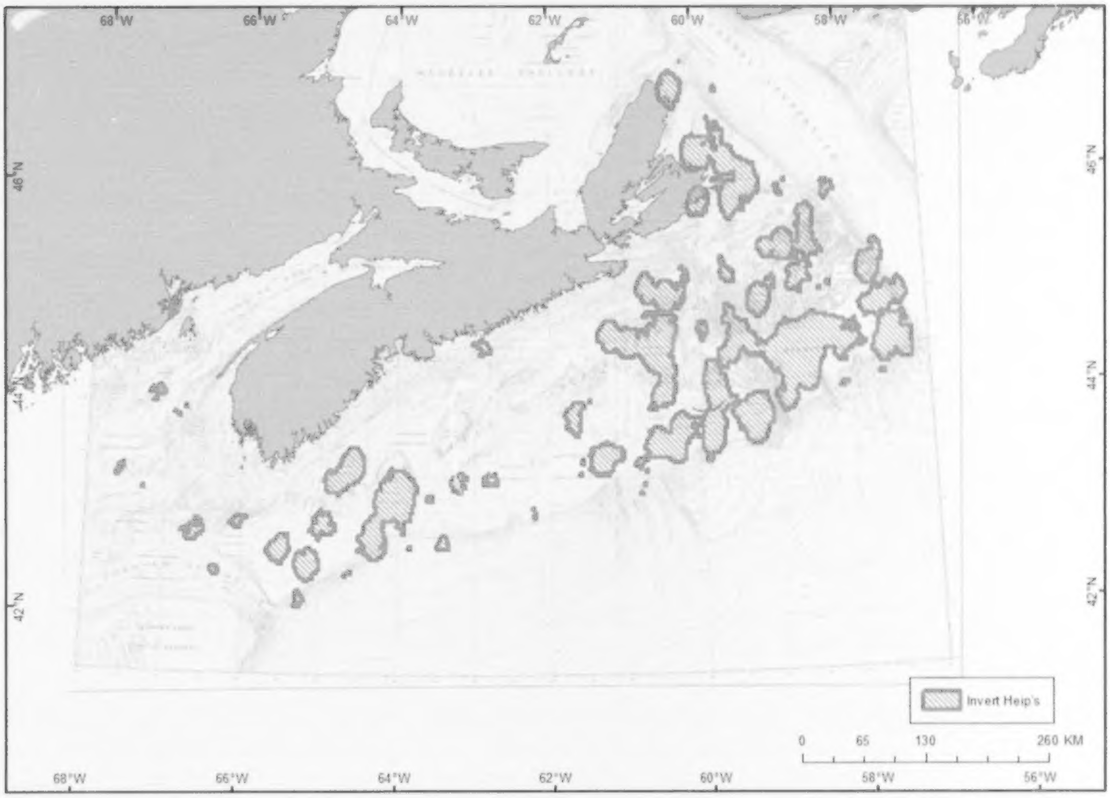

Figure 4. Areas of high invertebrate species evenness (Heip's Evenness Index) based on the DFO summer Research Vessel data.

Important Habitat for Fishes and Invertebrates

Important habitat data layers were updated or created for a suite of fish species using summer, spring and fall DFO RV survey data. The summer RV survey has taken place annually since 1970, so this large time series was divided into five fishing eras based on the approach used by Horsman and Shackell (2009). For the summer habitat layers, a composite layer was also created for each species by combining the layers for each of the five fishing eras. Spring and fall data were limited to the periods of 1979 to 1985 and 1978 to 1984, respectively. As already described, areas of high biomass were identified by calculating the total biomass per tow and then creating a continuous surface using an Inverse Distance Weighted interpolation. The data layers were then classified into quintiles and the areas within the top quintile (i.e., top 20%) were considered areas of high biomass and important habitat. Following Horsman and Shackell (2009), it was assumed that areas where high biomass of a particular species was consistently observed in the RV surveys over the five fishing eras are important fish habitat (example shown in Figure 5).

The list of fishes included in this analysis is the same as that used by Horsman and Shackell (2009) and includes ecologically significant species, other dominant or common species, and depleted species. Depleted species were defined here as species that have been assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) or listed under the

Species at Risk Act as Threatened or Endangered, or are below the limit reference point in the DFO Precautionary Approach Framework (DFO 2006a, 2006b). In the rare case where these two assessments differ in stock status or distribution, the best available information was used.

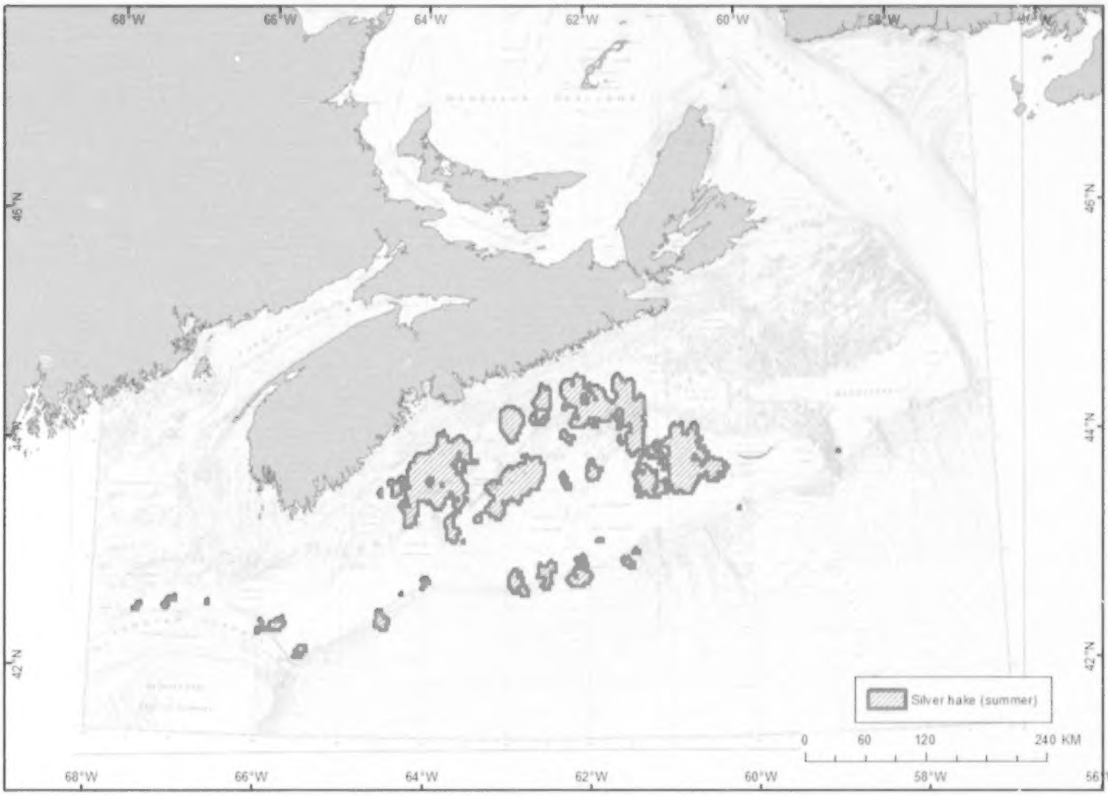

Figure 5. Important habitat data layer for Silver Hake based on the DFO summer Research Vessel data. Map represents a composite of five fishing eras between 1970 and 2013.

The RV survey data were used to map important habitats for sixteen invertebrate species identified by Tremblay et al. (2007). Prior to 1999, identification of these species in the survey was not reliable, so only summer data from 1999 to 2013 were used to create the invertebrate layers. Since 2007, the list of species that are accurately and consistently recorded in the RV summer survey has expanded considerably, so a broader suite of species can now be mapped.

Horsman and Shackell (2009) used data from the Scotian Shelf Ichthyoplankton Program (SSIP) to map abundance patterns of larval fishes, which ran from 1978 to 1982. Eight species-specific larval fish abundance layers were included in the EBSA evaluation.

Critical Habitat for Endangered Species

Critical Habitat for the endangered North Atlantic Right Whale and Northern Bottlenose Whale were plotted and considered in the EBSA evaluation.

Due to the limitations associated with the cetacean sightings data, habitat suitability models have been examined for predicting the distribution of cetaceans in the bioregion (Gómez-Salazar and Moors-Murphy 2014). Further development of these models is required before they can be used in identifying and evaluating EBSAs.

Important habitat for the Endangered Leatherback Sea Turtle was also considered in the evaluation.

Corals and Sponges

Coral and sponge occurrences were mapped using data from the Maritimes Region Coral Database, which includes records collected during the DFO RV surveys, bycatch records from commercial fisheries (Fisheries Observer Program), local ecological knowledge (LEK) studies and remotely operated vehicle (ROV) surveys (Cogswell et al. 2009). Due to sampling biases and other limitations, these data cannot be used to develop comprehensive relative distribution maps for the bioregion. Kenchington et al. (2010) have, however, used the DFO summer RV survey data to complete a Kernel Density Analysis to identify high concentrations of certain corals and sponges. The areas they identified for sponges were taken into account in the current exercise.

In addition to corals and sponges, high concentrations of other structure providing benthic invertebrate species may qualify as EBSAs (Kenchington 2014). However, these species were not considered in the current evaluation.

Important Areas for Seabirds

Areas of high relative abundance for eight seabird functional guilds were mapped using data from Environment Canada, i.e., the Programme intégré de recherches sur les oiseaux pélagiques (PIROP) and Eastern Canada Seabirds at Sea (ECSAS) databases. Count data, including true zeroes (absences), were collected from 1965 to 1992 (PIROP) and 2006 to present (ECSAS) using ships of opportunity, following a standardized protocol (Gjerdrum et al. 2012). As spatially and temporally reliable access to resources can have fitness implications for the species considered, birds represented are assumed to be congregated and making use of food resources expected to be present in these areas. Birds were grouped into functional guilds in order to more clearly emphasize links to such underlying ecological processes.

Distinct Physical Conditions

Distinct physical conditions were plotted based on previous research (Kostylev and Hannah 2007) to identify areas with different scope for growth and natural disturbance regimes. Areas of very high scope for growth, very low scope for growth, and very low natural disturbance were highlighted within certain EBSAs.

Sources of Uncertainty

Significant gaps exist in the available ecological and biological data for the Scotian Shelf Bioregion. For instance, less information is available for the slope and deeper-water environments than the shelf; demersal environments are generally better-studied than the pelagic and meso-pelagic realms; and relative distribution information is not available for certain taxonomic groups (e.g., cetaceans, sharks, tunas, sponges). As a result, many of the data layers compiled for this exercise pertain to the demersal communities of the Scotian Shelf.

The DFO RV data were used to create many of the data layers considered in this analysis, so it is important to acknowledge the limitations of these surveys. For example, certain parts of the shelf are not sampled due to untrawlable bottom. The largest example is the area off southwest Nova Scotia. The seasonal coverage of the RV data is also limited. The only survey that spans the majority of the shelf for an extended time series is the summer RV survey. Shelf-wide surveys in the spring and fall only occurred during a limited period from the late 1970s to the mid-1980s. Spring surveys on the eastern Scotian Shelf were completed from 1986 to 2010, but they were not used in this analysis due to their limited coverage. In addition, the RV survey gear does not capture all species equally. The catchability of a species is a function of its availability to the gear (e.g., the vertical distribution of the species), its vulnerability to the gear (e.g., herding effects, net avoidance, and mesh selectivity), and its spatial and seasonal distribution (Edwards 1968). As a result, the survey estimates for some species are not useful. For certain

species, habitat suitability modelling can be used where the RV survey does not effectively cover their habitat (e.g., Cusk). Other fish species that are not effectively captured by the RV survey (e.g., Atlantic Argentine) have been excluded from this analysis.

CONCLUSIONS AND ADVICE

Eighteen EBSAs were described and delineated in the offshore component of the Scotian Shelf Bioregion. Seventeen of the EBSAs occur on the Scotian Shelf or Scotian Slope and one EBSA was identified in the deeper waters beyond the slope. The EBSAs are presented in Figure 1 and described in Appendix 1. It was noted that areas not identified as EBSAs as part of the SEO exercise (Doherty and Horsman 2007) were not considered in this review (except for St. Anns Bank).

Further work is needed to finalize or refine several of the data layers considered in this review (see below). No priority was assigned to these different areas of research.

The initial analysis to identify areas of persistent high chlorophyll concentrations in the bioregion should be refined by splitting the shelf waters into eastern and western components due to the differences in the oceanographic environments of these areas. The deep water component of the analysis should begin at the 200 m isobath and be adjusted to include the deep waters of the Laurentian Channel. Separate seasonal layers should also be developed to account for the significant variability in chlorophyll concentrations throughout the year. Additional work is also needed to describe the linkages between surface primary productivity and the benthos (i.e., benthic/pelagic coupling) and investigation into understanding the horizontal transport of phytoplankton in the bioregion.

Further analysis is required to develop a more complete understanding of the spatial and temporal patterns in biodiversity in the bioregion. The results presented clearly demonstrated different patterns between the three species-based biodiversity indices, i.e., Species Richness consistently exhibited a different pattern from the Heip's Evenness and the exponential of Shannon-Weiner Indices. The implications of this result require further investigation. These three biodiversity indices should be plotted for other available broad-scale data (e.g., SSIP, ECSAS), and seasonal variation in the different indices should be investigated. However, species-level diversity is just one aspect of diversity. Functional trait diversity, such as diversity of trophic guilds, size structure and other metrics must be explored to fully contribute meaningful scientific advice about the biodiversity on the Scotian Shelf. Further, the relationship between biodiversity and ecosystem functioning is an on-going area of research on the Scotian Shelf.

The fish and invertebrate species considered in this exercise can be organized into functional groups based on body size and preferred prey (Shackell et al. 2012). The identification of important areas for functional groups may be more relevant to the identification of EBSAs than individual species because functional groups can be clearly associated with important ecosystem processes.

A more in-depth analysis of the DFO RV survey data could help identify areas required for important life-history stages (e.g., juvenile and spawning areas) for certain species or functional groups. Identifying these areas would help address the Fitness Consequences EBSA criterion, which was not dealt with in a systematic manner in the current EBSA evaluation exercise.

Prior to 2007, reliable species identification for invertebrates in the RV survey was limited to a subset of species. Since 2007, the list of species that are accurately and consistently recorded in the RV survey has expanded considerably, so a broader suite of species can now be mapped. As a result, species distribution maps could be created for a much larger suite of species in the future.

In addition to corals and sponges, high densities of certain benthic invertebrate species may qualify as EBSAs. These species, such as *Boltenia ovifera* (a stalked tunicate), could be

mapped where sufficient data are available and these features could contribute to future EBSA evaluation processes.

Where sufficient relative distribution information does not exist, habitat suitability modelling approaches can be explored to predict where the most important habitats are for certain species. Species distribution models have already been developed for certain coral and sponge species in other areas of the Northwest Atlantic. Similar models should be created for important coral and sponge species in the Scotian Shelf Bioregion. Building on the work of Gomez-Salazar and Moors-Murphy (2014), habitat suitability models for cetaceans should be refined and tested to develop a more comprehensive understanding of the distribution of common species in the bioregion. Such models would be valuable in future EBSA evaluation exercises. Habitat modelling approaches could also be used to generate distribution maps for seabirds, sea turtles and large pelagic fishes. Species tracking information would also be valuable in understanding the distribution and movements of highly mobile taxa.

The list of EBSAs presented in this report will require further refinement in the future as additional information becomes available and the research questions raised through this process are answered. Further investigation is required to refine several of the larger EBSAs, such as the Scotian Slope, Laurentian Channel, and Georges Bank. Other available survey data should be analyzed to identify the most ecologically and biologically significant locations within these broadly defined EBSAs. Discrete physical features (e.g., submarine canyons) should also be delineated and described within these EBSAs.

SOURCES OF INFORMATION

This Science Advisory Report (SAR) is from the February 18-20 and March 24, 2014 Updating Offshore Ecologically and Biologically Significant Areas in the Scotian Shelf Bioregion. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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APPENDICES

Appendix 1. Summary of proposed EBSAs in offshore Scotian Shelf Bioregion. Key ecological or biological features contained within each EBSA are noted as well as potential future work required. DFO EBSA criteria abbreviations: U = Uniqueness, A = Aggregation, FC = Fitness Consequences, R = Resilience, and N = Naturalness. Dash indicate that criteria are not considered to apply.

EBSA	Key features	DFO Criteria					Potential Future Work
		U	A	FC	R	N	
1. Jordan Basin and Rock Garden (1,824 km^2)	High primary productivity, unique and sensitive benthic community (Rock Garden), important for groundfish (Cusk, White Hake, redfish, Spiny Dogfish), high fish biomass, high fish species diversity (richness, ESW[1]), high invertebrate species diversity (richness, evenness), high larval fish genus richness, high small invertebrate species richness, important seabird habitat (most functional guilds)	x	x	x	x	-	Delineate the Rock Garden feature and other similar communities and assess the significance of this EBSA to the North Atlantic Right Whale.
2. Canadian portion of Georges Bank (7,014 km^2)	High primary productivity, important for groundfish (Atlantic Cod and Haddock spawning and nursery area, Cusk), Atlantic Herring spawning area, high scallop abundance, high larval fish genus richness, unique benthic community (tube worm), Porbeagle matting ground, important seabird habitat (all functional guilds)	x	x	x	-	x	Delineate discrete features (e.g., tube worm habitat) within this large EBSA. Georges Bank survey data should be analyzed.
3. Northeast Channel (2,589 km^2)	Highest densities of large and sensitive gorgonian corals in the region, high primary productivity, important seabird habitat (most functional guilds), important for Cusk	x	x	x	x	-	Describe the fan component of this EBSA through new surveys or analysis of existing data.
4. Browns Bank (4,308 km^2)	Moraine feature along northern flank may serve as a natural refuge, important for groundfish (Atlantic Cod and Haddock spawning and nursery area, halibut nursery area, Cusk, American Plaice, Atlantic Wolffish, Winter Skate, Yellowtail Flounder), important for commercial invertebrates (abundant large lobsters, Sea Scallop), high larval fish genus richness (partial gyre promotes retention), high fish and invertebrate biomass, high invertebrate species diversity (richness, ESW, evenness), high small invertebrate species richness, important seabird habitat (most functional guilds)	x	x	x	x	-	Delineate discrete features (e.g., moraine feature) within this EBSA.
5. Roseway Basin (3,158 km^2)	Endangered North Atlantic Right Whale Critical Habitat, high copepod biomass, important for groundfish (redfish nursery, Smooth Skate, American Plaice, Atlantic Cod, Cusk), high fish biomass, high fish species diversity (richness), important seabird habitat (several functional guilds), moraine feature, pockmarks (possible chemosynthetic communities)	x	x	x	x	-	Research needed to assess the importance of this EBSA to other cetacean species and delineate and describe the moraine feature and pockmarks.

EBSA	Key features	DFO Criteria					Potential Future Work
		U	A	FC	R	N	
6. Emerald Basin and the Scotian Gulf (8,513 km^2)	Unique benthic community [Russian Hat sponges (*Vazella pouralesi*)], unique temperature and salinity regime, high zooplankton biomass in basin, important for groundfish (Silver Hake, Pollock, White Hake), high fish and invertebrate biomass, high fish species diversity (ESW, evenness), high invertebrate species diversity (richness), high small fish and small invertebrate species richness, important for Northern Sandlance and Shortfin Squid, pockmarks in basin (possible chemosynthetic communities), important seabird habitat (most functional guilds), very low natural disturbance	x	x	x	x	-	Research required to determine the relative distribution of Russian Hat. Also should assess the importance of this EBSA to cetaceans and better-describe the pockmarks in the basin.
7. Emerald-Western-Sable Island Bank Complex (17,900 km^2)	Important for groundfish (Haddock spawning and nursery area, Atlantic Cod spawning area, Winter Skate, Silver Hake, Atlantic Halibut), Atlantic Herring, high larval fish abundance and diversity (gyre leads to retention), commercial and non-commercial invertebrates, high fish and invertebrate biomass, high fish species diversity (ESW, evenness), high invertebrate species diversity (richness, ESW, evenness), important seabird habitat (most functional guilds), Western Gully area of potential significance to cetaceans	-	x	x	x	-	Delineate discrete features within this large EBSA. Assess the importance of this EBSA (particularly the Western Gully area) to cetaceans.
8. Sable Island Shoals (1,297 km^2)	Unique coastal habitat in the offshore, world's largest Grey Seal breeding colony, nursery area for many fishes, area of high primary productivity, important seabird habitat (plunge diving piscivores, shallow diving piscivores, shallow pursuit generalists), high invertebrate biomass, high invertebrate species diversity (ESW, evenness), high fish species diversity (ESW, evenness)	x	x	x	-	-	Further research could help define a more ecologically meaningful boundary for this EBSA.
9. Eastern Scotian Shelf Canyons (7,434 km^2)	Unique submarine canyon ecosystems (The Gully is largest off eastern North America), canyons are Critical Habitat for Endangered Northern Bottlenose Whale, important for other cetaceans (Blue Whale, Sowerby's Beaked Whale), diverse and sensitive benthic communities (diverse and abundant coldwater corals), high fish and invertebrate species diversity (richness, ESW, evenness), high fish and invertebrate biomass, important for groundfish (Atlantic Cod, Atlantic Halibut, redfish, Smooth Skate, White Hake), important seabird habitat (most functional guilds)	x	x	x	x	-	Delineate discrete features within this large EBSA.
10. Middle Bank (2,748 km^2)	Important for groundfish (Atlantic Cod spawning and nursery area), high larval fish genus richness, high invertebrate species diversity (ESW, evenness), high small fish species richness, high invertebrate biomass, important seabird habitat (most functional guilds)	-	x	x	-	-	This EBSA is not well-studied so research on the structure and function of the local ecosystem would be beneficial.
11. Canso Bank and Canso Basin (4,113 km^2)	High fish species diversity (ESW, evenness), high invertebrate species diversity (ESW), high larval fish genus richness, high invertebrate biomass, high small fish species richness, commercial (Northern Shrimp, Snow Crab)and non-commercial invertebrates, high primary productivity, important for groundfish (American Plaice), Sandlance, relatively high naturalness (bank portion), important seabird habitat (several functional guilds)	-	x	x	-	x	This EBSA is not well-studied so research on the structure and function of the local ecosystem would be beneficial.

EBSA	Key features	DFO Criteria					Potential Future Work
		U	A	FC	R	N	
12. Misaine Bank (4,599 km^2)	High fish species diversity (evenness), high invertebrate species diversity (ESW, evenness), high invertebrate biomass, important for commercial invertebrates (Northern Shrimp, Snow Crab), important for groundfish (Atlantic Cod, American Plaice, Thorny Skate), Sandlance, relatively high naturalness (bank portion), important seabird habitat (particularly pursuit diving piscivores)	-	x	x	x	x	This EBSA is not well-studied, so research on the structure and function of the local ecosystem would be beneficial.
13. Eastern Shoal (3,397 km^2)	Large, shallow sand body is unique, important for groundfish (Atlantic Cod, American Plaice, Winter Skate, Thorny Skate), Sandlance, unique shallow sand body, commercial invertebrates (Surf Clams, scallops, quahogs), high fish species diversity (evenness), high invertebrate species diversity (ESW, evenness), important seabird habitat (several functional guilds)	x	x	x	x	-	No further work identified at this time.
14. Stone Fence (44 km^2)	Unique and sensitive benthic community (*Lophelia pertusa* reef)	x	x	-	x	-	Further in situ research in the area surrounding this EBSA could identify additional Lophelia reefs.
15. Laurentian Channel (21,484 km^2)	High primary productivity, high zooplankton biomass, important for groundfish (overwintering area for Atlantic Cod and other species, redfish, White Hake), abundant redfish larvae, high fish biomass, sandlance, migratory route (groundfish, cetaceans, Leatherback Sea Turtle), sensitive benthic communities (sea pen fields), high invertebrate species diversity (evenness), high small fish and small invertebrate species richness.	-	x	x	x	-	Delineate important features within this large EBSA. Additional survey data should be analyzed.
16. St. Anns Bank (4661 km^2)	High primary productivity, high larval fish genus richness, important for groundfish (used by 3 populations of Atlantic Cod, Atlantic Wolffish), high fish and invertebrate species diversity (ESW, evenness), high small fish species richness, located on a migratory route (groundfish, cetaceans, Leatherback Sea Turtle), sensitive benthic communities (sea pen fields), important for seabirds (particularly plunge diving piscivores)	x	x	x	x	-	No further work identified at this time.
17. Laurentian Fan Cold Seep Communities (52 km^2)	Unique, diverse and highly productive chemosynthetic cold seep community	x	x	-	-	-	Very little is known about this area so additional research is needed.
18. Scotian Slope (72,800 km^2)	High primary productivity, high fish species diversity (ESW, evenness), high small fish and small invertebrate species richness, important for groundfish (Cusk, redfish, White Hake, Thorny Skate, Atlantic Halibut), migratory route (cetaceans, large pelagic fishes), important for seabirds (most functional guilds), unique habitats and sensitive benthic communities	-	x	x	x	-	Further analysis required to delineate important features, such as specific canyons, within this large EBSA. Additional survey data could be analyzed.

[1] Exponential of Shannon-Weiner Index

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